P 1.12 SNOW LEVEL FORECASTING METHODS AND PARAMETERS; TWO PRACTICAL EXAMPLES ON EASTERN ITALIAN ALPS

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1. INTRODUCTION

In this work the methods to forecast the snow level in a precipitation event are investigated, considering the pertinent forecasting parameters and the necessary knowledge of the specific territory which will be interested by the precipitation event. The snow level represents the altitude over which the precipitation is mainly (90%) solid (Kappenberger/Kerkmann, 1997), and not necessarily the altitude at which a snow accumulation is observed on the ground.

Then two examples concerning two typical situations on the Venetian Alps (Fig. 1) are shown.

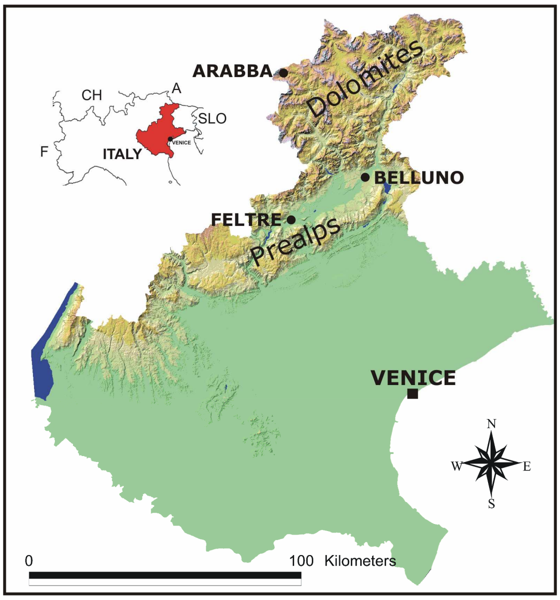

Fig. 1: Venetian Alps' geographical map

2. FORECASTING METHODS AND PARAMETERS

The forecasted freezing level, the Wet Bulb Pseudo Potential Temperature at different levels, humidity fields, vertical motions, dew point temperatures at different pressure altitude, temperature's gradients, forecasted sounding (temperatures' identification in the boundary level) and forecasted precipitation maps are used to determine the snow level in a forecasted precipitation event.

In order to determine the snow level, the first parameters to consider are the freezing level and the forecasted precipitation intensity; it is simply possible to approximately determine the snow level considering the intensity of the forecasted snowfall: snow level 200-300 m below the frost line in case of light precipitation, 400-500 m below the frost line in case of moderate precipitation, and 600-700 m below the frost line in case of heavy precipitation, also more in case of snow-rashes or thunderstorms. Nevertheless, considering only these two parameters, the snow level forecasting may result not precise. Many other parameters are necessary to correctly determine the snow level.

First of all it is necessary to know the real forecasted intensity of precipitation; so, many forecasting parameters must be considered, as humidity fields in integrated vertical layers, vertical motions, temperature's vertical gradient, and, in the end, forecasted precipitation maps. After determining the forecasted intensity, it is necessary to consider another very important condition: it is necessary to know if, before the event, there are isothermal or thermal inversion conditions in the boundary layer, analyzing the radiosounding and the data coming from the local stations' network.

In case of thermal inversion or isothermal conditions the models' information about the wind in the low levels, observed trough vertical section of the interested area, and the analysis of the forecasted radiosounding (Fig. 2), are necessary to determine if and for how long the thermal conditions can be kept. Especially the forecasted soundings help to try to determine the forecasted thermal conditions of the low levels, and it is very important in case of pre-existing isothermal or thermal inversion conditions.

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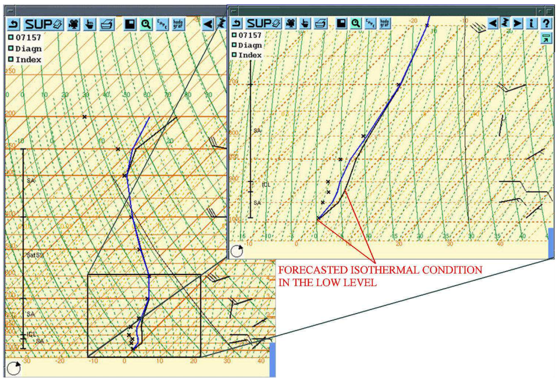


Fig. 2: example of forecasted radiosounding by ARPEGE global model

In case of frontal situation the observation of the front gives more information, analyzing if the front is an ANA or a KATA front; in the first case no turbulent air motion is waited (Fig. 3), so that the initial thermal condition of the boundary layer can remain unchanged longer; in case of strong snowfall the snow level can significantly fall down due to a strong air cooling by snow-melting.

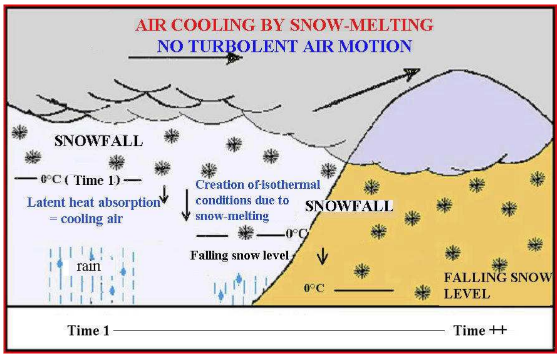


Fig. 3: non turbulent air motion (ANA front)

In case of a KATA front turbulent air motion is likely and no persistent thermal inversion or isothermal conditions are to be waited (Fig. 4). Even in case of heavy snowfall no significant snow level falling down must be waited.

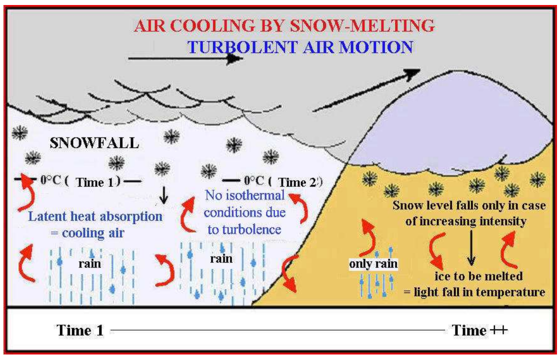


Fig. 4: turbulent air motion (KATA front)

After a KATA or occluded front crossing a cold air downdraft (density flux) may occur, which can make the snow level fall down at the end of precipitations. Often, especially considering a regional scale, the models are not able to forecast this kind of phenomenon, so that the snow level forecast can be difficult.

Vertical cross section (Fig. 5) from models and other synoptic information (like SATREP images) can help to understand what kind of front is waited.

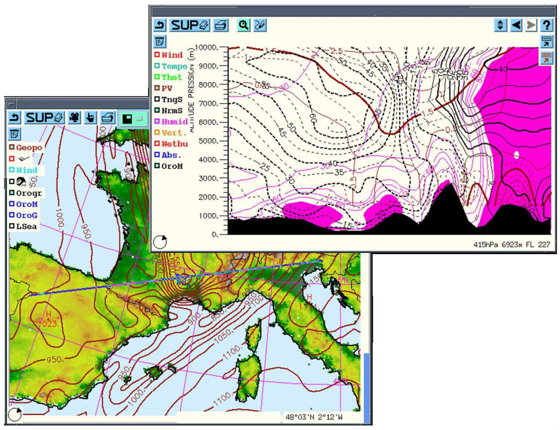


Fig. 5: example of vertical cross section by ARPEGE global model

Then, considering the evaluation of the front type, analyzing the models' winds indication in the low layers, it is possible to approximately establish for how long the isothermal or thermal inversion conditions can be kept in a certain area. After the removing of the low layer cold air, the determination of the snow level follows up the general rule of the intensity referred to the freezing level.

Another fundamental knowledge concerns the orography: for example, usually in the Venetian prealpine areas eventual cold air in the boundary layer can remain for shorter time, due to the direct influence of the southern mild flux, which can quickly remove isothermal or thermal inversion conditions, especially on the slopes directly exposed to the Po Valley; so a short time after the beginning of snowfall, many times the snow level depends only by the freezing level and the intensity of precipitation. Often, in presence of strong southern flux, even in case of heavy snowfall, the snow level can't fall down respect to the frost, because of the persistent turbulent air mixing, which does not permit a significant air cooling by snow-melting. In the most internal areas of the Venetian mountains (Dolomites), where the valleys are more enclosed and deeper and more far from Po Valley and Adriatic Sea, the low level cold air with isothermal or thermal inversion conditions can remain longer, sometimes also 24/36 hours; so, in case of non turbulent front, even in case of strong southern flux aloft, and even in case of not heavy snowfall, the snow level can result significantly lower than the freezing level. In case of absolutely non turbulent air motion in the low layers, in the most internal dolomitic valleys often the snow level remains very low also if the freezing level is rising.

The shape of the valleys is another orographic parameter to consider: in the deepest and enclosed valleys, in case of non turbulent air motion and heavy snowfall, the snow level can significantly fall down also without initial isothermal or thermal inversion conditions, because of the smaller volume of air which must be cooled by the snow-melting process (Fig. 6). Then the snow can fall down also many hundreds meters under the freezing level.

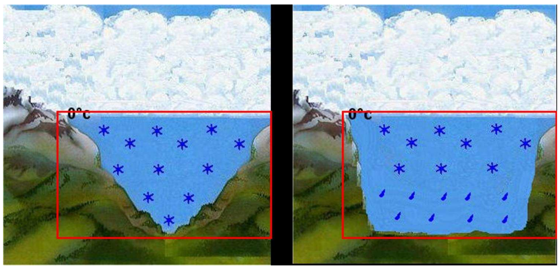


Fig. 6: smaller volume of air to be cooled in the deepest and enclosed valleys

At the end, it is also necessary to remark that a very good knowledge of the confidence of the models, especially concerning the information about the boundary layer's thermal conditions, can give good answer to the forecaster; so it is necessary to compare the real-time radiosounding and local stations' information and other observations with the data forecasted by the models for the same time. For example the comparison between the recorded temperatures and the forecasted ones (air temperatures and dew point temperatures) is an important step to well start the snow level forecasting.

3. TWO PRACTICAL EXAMPLES

After the analysis of the methods to forecast the snow level in a precipitation event, two examples of snowfall on the Venetian mountains (eastern Italian Alps) are analyzed.

3.1. LOW SNOW LEVEL ON THE VENETIAN PREALPS

Between the 10th and the 11th March 2004 the Venetian Alps were interested by precipitation mostly snowy, locally heavy, especially on the prealpine and southern-Dolomites areas.

The event was caused by an Upper Level Low coming from northern Europe to France, directly affecting Northern Italy (Fig. 7).

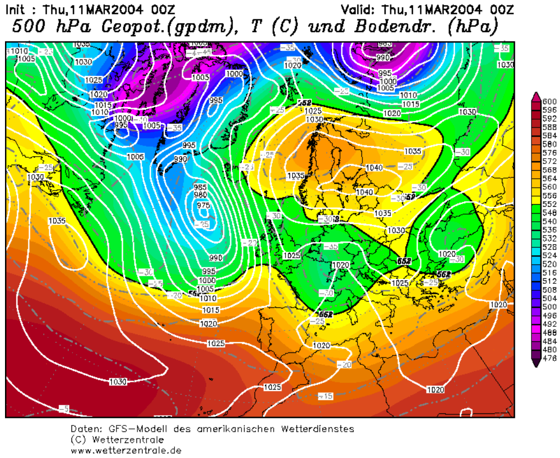


Fig. 7: GFS model 500 hPa geop. and soil level pressure analysis (0.00 March 2004 the 11th)

In the previous days cold air in the low layers caused very Low temperatures in the valley bottoms, the prealpine valleys too. During the event, time after time milder air in the low layer entered into the North-East Po Valley, with a progressive rising of the snow level on the Venetian Prealps.

On the Belluno Valley the precipitation was at first snowy everywhere. But in the area near Belluno city the snow soon turned in rain; this change run up to the western part of the valley during the precipitation, but in the closest area (near the city of Feltre) the precipitation remained as snow for all the event, even if the area is at lower altitude than Belluno.

The reasons of this difference must be found in the effects on the snow level of the turbulent air motion nearby to the ground, considering the influence of the low level flow in different orographic conditions. Different times of entering mild low level flow determines the change between snow and rain. In the closest part of the valley no mild low level flow enters at all, so that the precipitation remains as snow for all the event, even if the freezing level is rising.

In fact, the Belluno Valley receives low level flows from East South-East, trough the area of Fadalto Pass, which directly faces to the Po Valley, not very far from Adriatic Sea. So that in case of southern flow in the low level, usually the eastern part of the Belluno Valley is interested by mild low level flux before than the western part. Some rather high relieves close the western area of the Belluno Valley, so that no mild flux can enter into the valley from West or South at the ground level (Fig. 8).

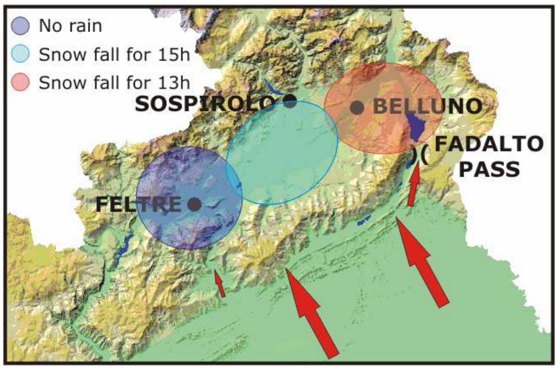


Fig. 8: mild low level flow entering direction on the Belluno Valley and different duration of snowfall on 2004 March the 10-11th

So the duration of the snowfall in different parts of the same valleys is very unlike (Fig. 9).

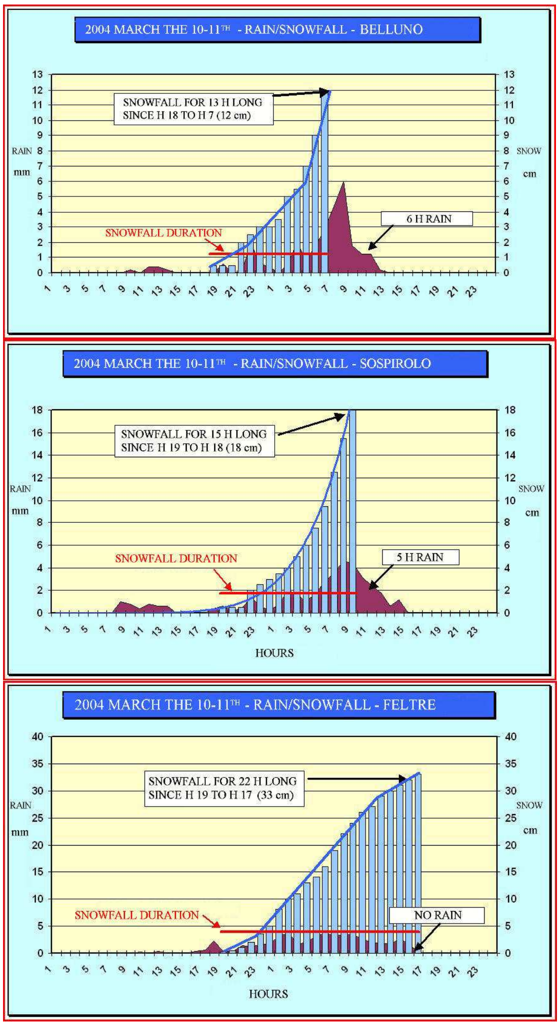


Fig. 9: duration of the snowfall in different places from East (Belluno) to West (Feltre)

The case of March 2004 looks very representative of the influence of orography on the low level flux. Analyzing the rising in temperatures in the valley bottom (Fig. 10), compared to the rising freezing level during the event, it is possible to notice that, where no turbulent air motion occurs in the boundery layer, the snow level can remain very low, also in case of relatively increasing temperatures aloft. In the areas directly exposed to mild low level flow, usually the snow level quickly rises, and is soon determined only by freezing level and snowfall intensity.

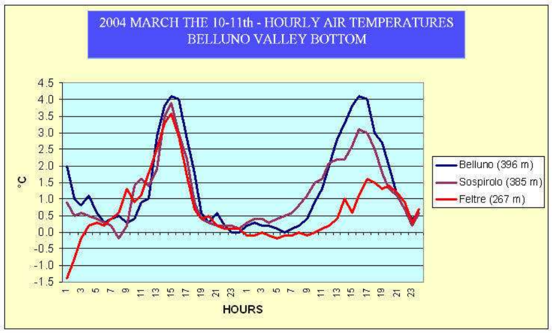


Fig. 10: hourly air temperatures in the Belluno Valley bottom

Good models' information about the low level flow in the interested area, especially by local models, about starting thermal condition compared to the real situation, and a good knowledge of the specific territory, help the forecaster to correctly estimate the starting snow level and the following changes related to the low level flux in different orographic situations.

3.2. FALLING SNOW LEVEL ON THE VENETIAN DOLOMITES

On April 2005 the 16th an Upper Level Low interested directly the Venetian mountains, causing disturbed/unsettled weather especially in the afternoon, with heavy precipitation and strong snowfall, also like rashes (Fig 11).

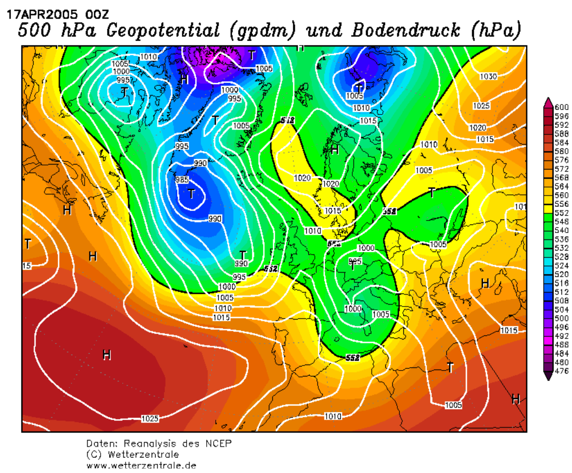


Fig. 11: GFS model 500 hPa geop. and soil level pressure analysis (0.00 April 2005 the 17th)

In a few time the snow level felt down from 1500/1700 m to 700 m in many Dolomitic valleys. This so strong and quick falling down was primarily determined by the high intensity of precipitation, which, due to a strong air cooling by snow-melting, permitted falling snow level many hundreds meters under the freezing level.

The analysis concerns the Agordino area, in the central Dolomites. Two section are investigated: Cordevole Valley, cross section A – B – C, and Biois Valley, cross section B – D (Fig. 12).

Fig. 12: Agordino area: Cordevole Valley cross section A – B – C; Biois Valley cross section B – D

Analyzing the temperatures' data of the local network's stations it is interesting to notice how, with increasing snowfall intensity, isothermal conditions forms in the valleys, especially the deepest ones.

In particular orographic position (Alleghe), which is very near to a high vertical slope (M.nt Civetta, 3220 m), likely turbulent air motion determined by orography causes no strong air cooling by snow-melting; so, even if elsewhere the snow level falls down to 700 m, nearby to Alleghe (1000 m) only rain is observed.

At the beginning of the event the freezing level is around 1950 m and the snow level around 1500/1700 m (Fig 13).

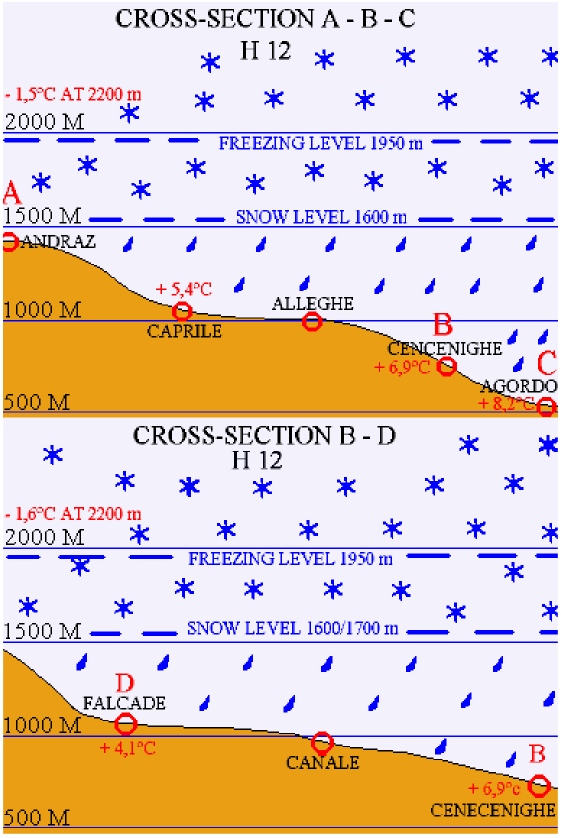
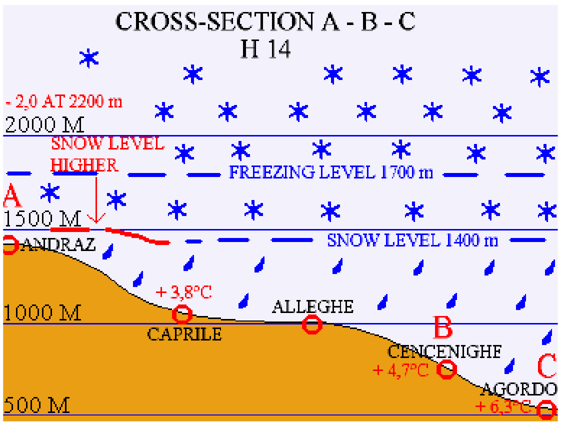


Fig. 13: freezing level and snow level H 12

Two hours later the freezing level is around 1700 m, but, where the intensity looks higher (Cross-section D – B. Falcade – Cencenighe), the snow level falls down very quickly (Fig. 14).



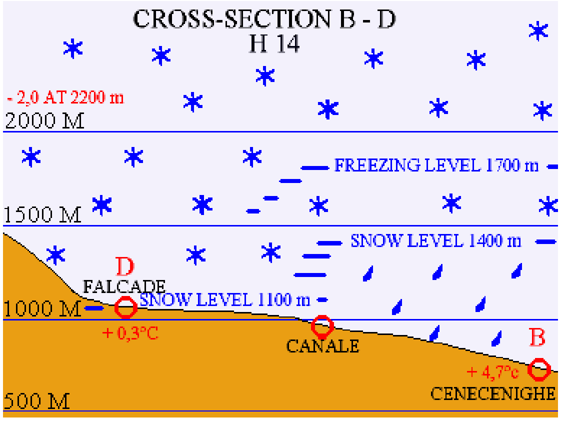


Fig. 14: freezing level and snow level H 14

Four hours after the beginning all the air column looks in isothermal conditions, except around Alleghe, where micro turbulent air conditions keep the snow level a little bit higher (Fig. 15).

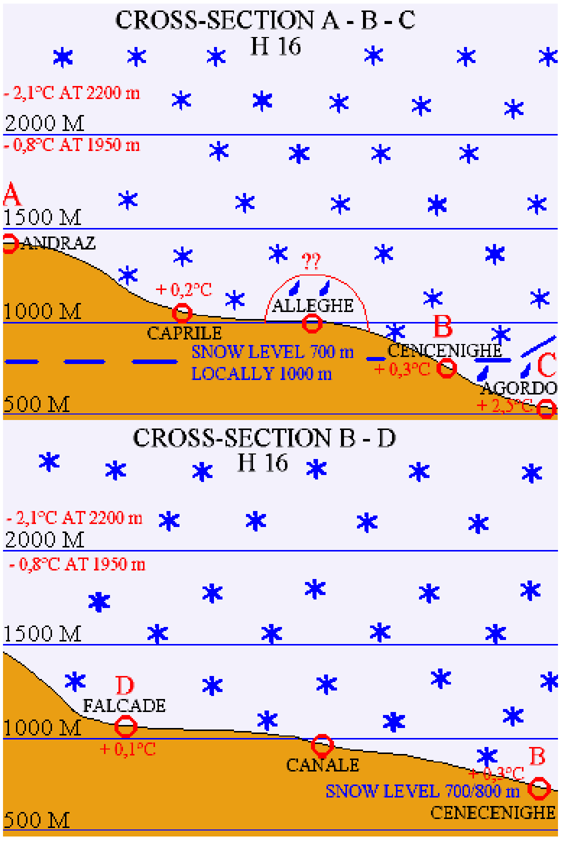


Fig. 15: freezing level and snow level H 16

In order to correctly forecast the snow level, in case like this, it is necessary to correctly analyze the kind of front coming and the forecasted intensity; good indications can come from models' vertical cross section and SATREP images. In case of non turbulent air motion (ANA front), the forecasted snow level could be lower than which one calculated with the simple rule of the freezing level compared to the intensity, even if no isothermal or thermal inversion conditions are observed before the event. The good knowledge of orography is important to estimate snow level falling down; so, it is possible to forecast a strong difference between freezing level and snow level, even if this difference can be strongly unlike in different valleys, strictly depending on single rash's intensity and local orographic conditions. A good forecast of the precipitation intensity looks fundamental to rightly forecast the snow level in case of non turbulent low layer air motion, especially in complex orographic situations.

4. CONCLUSIONS

The forecast of the snow level often represents a real problem for the forecaster approaching a precipitation event on a complex mountain area.

Some methods, less or more empirical, try to estimate the snow level, considering many parameters, for example freezing level, precipitation intensity, wet-bulb temperatures, or analyzing the problem with a microphysical approach.

Nevertheless, in the experience of the ARPAV Avalanche Centre's forecasters, in order to correctly forecast the snow level, a single method can not be applied.

In any situation it is necessary to analyze different parameters, any times differently pertinent for the single event. Primarily it is always necessary to compare the real observed situation with the forecasted data, in order to have a good forecast starting. Then it is important to determine the kind of configuration coming (frontal situation, isothermal or thermal inversion starting conditions, potential instability with heavy precipitation, etc.).

An absolutely very good knowledge of the territory over which the forecast insists is also fundamental to give a detailed snow level forecast. Without this knowledge it is not possible to correctly forecast the snow level in a restricted area, but it is only possible to express a not very representative average value, which can not be the aim of the forecast.

A strong interaction between forecasting models' parameters, observational data and forecaster's experience and knowledge of territory, is the key to produce a detailed snow level forecast on a mountain area.

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